TYPE 1280-A

RECTIFIER TEST SET

NOTE

This material covers only the details of operation. It should be used with Technical Publication B-14, which gives a general description of the instrument.

GROUND CONNECTION. A three-terminal power cord is provided so that the chassis and cabinet of the instrument will be grounded when a suitable outlet is available. One side of the power line is generally at ground potential, and a check should be made to be sure that this side is connected to the low-potential side of the measuring circuits. To make this check, plug in the instrument, and see that the TEST switch is OFF. Turn on the power switch and the pilot lamp should light. Measure the ac voltage between the lower (black) EXT LOAD CAP terminal and ground. Reverse the line connection if required. If no outlet of the proper polarity is available, the cord can be reversed by removing the ground pin. When this is done, a separate ground connection should be made to the cabinet.

Note that the cabinet is not connected to the measuring circuits, so the above precautions are not to protect the operator. They are to facilitate balancing out the effects of wiring capacitances on the measurement of very small reverse leakages and give maximum measurement accuracy.

GENERAL. Make sure that the TEST switch is turned to the OFF position and turn on the POWER switch. The control switches below the two right-hand meters should be turned to the ZERO position. After a few seconds these meters will deflect momentarily and return to readings near zero. After a warm-up period of a minute or so, the ZERO ADJ knobs can be used to correct the zeros if required.

Connect the rectifier to the test terminals, observing the correct polarity. (Note: When the TEST switch is OFF, both test terminals are disconnected from the line to protect the operator. The red warning light indicates when voltage is applied.)

Turn the ADJUST INPUT Variac®Autotransformer to zero and set the multiplier for the INPUT VOLTS meter at the desired range. Set the LOAD CURRENT meter multiplier at the desired scale and the ADJUST knob counterclockwise. See that the RECORDER switch is set to OFF.

For preliminary checking of the instrument the SERIES RESISTANCE can be set to 4.7 ohms and the LOAD CAPACITANCE to 100 μf. Choice of resistance and capacitance to meet specified test conditions is discussed in a following section. It should be noted that, because of non-linearity, tests with zero load capacitance should not be made using the internal vacuum-tube load of the instrument, but only with an external resistance load. The instrument is primarily intended for capacitive load tests. These apply a highly peaked current waveform to the rectifier, such as is encountered in actual operation, and give a more sensitive indication of rectifier quality.

MEASUREMENT OF REVERSE LEAKAGE AND MAXIMUM PEAK-INVERSE VOLTAGE. With the preliminary settings as described in the section above, turn the REVERSE LEAKAGE switch to the range corresponding to the rated reverse leakage of the rectifier. Set the range switch of the lower right-hand meter at PEAK INVERSE, and turn the operating switch to TEST. Gradually increase the input voltage, noting the reading of the REVERSE LEAKAGE meter as a function of peak-inverse-voltage as shown on the PEAK INVERSE meter. Selenium and germanium rectifiers show appreciable leakage at all voltages, good low-power silicon rectifiers may show no readable leakage (above a fraction of a microampere) until the Zener breakdown voltage is approached. For selenium or germanium rectifiers the leakage may be noted at rated PIV or the voltage increased until a specified reverse leakage is obtained, and the PIV noted for rated leakage. For low-leakage silicon rectifiers having a sharp breakdown or Zener voltage, the reverse leakage range switch should be set to the most sensitive range (0.15 ma) and the voltage very gradually increased until the breakdown point is reached. The PIV corresponding to, say, 10 or 20 μa leakage can be taken as the Zener voltage. The sensitivity of the instrument makes it possible to make this test without danger of burning out the rectifier. The direct-reading

PIV meter gives the breakdown voltage accurately and conveniently.

Note: The reading of the Peak Inverse Voltage meter may drift up scale to several hundred volts when the TEST switch is OFF and no rectifier is connected to the test terminals. This need cause no concern and occurs because the grid of the PIV tube is left floating under these conditions.

MEASUREMENT OF VERY LOW REVERSE LEAKAGE. Below the breakdown point, some silicon rectifiers exhibit reverse leakage of the order of 10^{-9} to 10^{-10} ampere at room temperature. This is below the range possible for dynamic measurements. Where reverse leakage measurements of a small fraction of a microampere must be made, we recommend the use of the General Radio Type 1230-A DC Amplifier and Electrometer. This will measure simply and directly static dc leakage down to 10^{-14} ampere and lower.

It should be pointed out that raising the rectifier temperature by means of an oven or hot plate to 100°C will increase the reverse leakage by a factor of the order of 100, and so will bring the leakage of many types of silicon rectifiers into the range of dynamic measurement.

MEASUREMENT OF FORWARD DROP. After it has been determined, as described above, that the reverse leakage is within reasonable limits, the lower right-hand meter can be switched from PEAK INVERSE to FORWARD DROP. The most sensitive range, 1.5 volts, should be used for silicon and germanium rectifiers; the higher ranges, 15 and 75 volts, for selenium and other types. The load current should be set at the selected value by means of the ADJUST control, and the forward drop read directly on the meter. As shown in the following section, "Selection of Load Circuit Constants," it is easy to observe the forward drop as a function of load current and maintain the peak-to-average current ratio constant. This is done by starting with a low value of input voltage and load current and then controlling the load current with the ADJUST INPUT control, making slight changes in the load control ADJUST setting to maintain the load current proportional to the input voltage. It is not satisfactory to fix the input voltage and vary the load, as the changes in forward drop caused by waveform variation are comparable to those caused by change in the average current.

For example, if a rectifier is to be tested at a maximum current of 300 ma and at an ac input voltage of 150, the readings might be taken as follows:

Input Volts	Load Milliamperes
50	100
75	150
100	200
125	250
150	300

This procedure is easy to carry through and has the great advantage of maintaining constant waveform.

Three ranges of the load current meter are available so that the load current can be accurately set at any value from a milliampere or less to 750 ma. To avoid burning of the contacts, the LOAD CAPACITANCE switch should not be turned when voltage is applied. To avoid excess plate dissipation in the vacuum-tube load, the upper load limit must be decreased at high applied voltages, as described below.

The forward drop meter reads the factor 2.5 times the full-cycle average of the forward voltage appearing across the rectifier. The factor 2.5 is used because a capacitive load reduces the true forward drop by about this amount compared with a resistive load. Full scale on the meter on the lowest range, therefore, is actually 0.6 volt true average value. In ordinary testing this does not usually concern the user. The values read directly on the meter scale are comparable with those obtained with other types of equipment with a resistive load, but differences in rectifier quality are more readily apparent. The variation of forward drop with load-current waveform is discussed in detail below, as is the choice of series resistance and load capacitance.

INTERACTION AND WARM UP EFFECTS. Both reverse leakage and forward drop depend on temperature, and thermal conditions must be standardized before accurate comparative data can be obtained. When maximum accuracy is not required, the simplest procedure is to test at room temperature and note for a particular rectifier type about how much the forward drop and reverse leakage change as the rectifier warms up with specified load current and peak inverse voltage. Provision is made, as described below, for use of a recorder to observe the variation with warmup of either the reverse leakage or the forward drop. More accurate results can be obtained with an oven or hot plate, or a thermocouple can be attached directly to the base of the rectifier and temperature readings correlated with the measured values of the rectifier parameters.

The testing of silicon and germanium rectifiers can frequently be simplified, because the only important interaction between the forward and reverse effects is through the junction tem-

perature rise. Reverse leakage, for example, can be measured without drawing forward current, provided that the difference in junction temperature is allowed for. Useful and accurate reverse-leakage data can be obtained in this way for rectifiers having forward current ratings greatly in excess of the load-current limit of the test set.

The situation is different with selenium rectifiers. With these the blocking layer becomes unformed to some extent during shelf life, when no voltage is applied. Fifteen minutes or longer may be required for final equilibrium conditions to become reestablished when the rectifier is put into service. Also, the reforming process sometimes affects the forward drop as well as the reverse leakage. The value of the initial surge of reverse leakage, too, is frequently of importance. Both this and the variation of leakage and forward drop during the reforming and warm up period can be conveniently observed with a recorder connected to the terminals provided on the test set. It is clear that with selenium rectifiers, in contrast with silicon and germanium types, separate measurements of forward drop or reverse leakage are of little value. The actual operating current and voltage must be applied simultaneously in order to get valid results, and time must be allowed for final equilibrium conditions to become established.

CHOICE OF LOAD CIRCUIT CONSTANTS. Most rectifiers used in power supplies for electronic equipment work into a capacitive load, resulting in a highly peaked current waveform. A well designed half-wave-power supply circuit includes enough series resistance to limit the rms current to about 2.5 times the direct current. This gives a peak current of about 8 times the average value. Similar conditions apply in doublers and other capacitor-input circuits. A rectifier working into a resistive load, on the other hand, is subjected to an rms current of only 1.57 times, and a peak current of only 3.14 times the dc load current. If rectifiers are tested with a resistive load, they are tested at a peak current of only about four tenths that encountered in a typical power supply application. The heating, also, is considerably less. A very important feature of the Type 1280-A Rectifier Test Set is that it can measure accurately the very small dynamic forward drop with highly peaked current waveforms. In order to obtain the best possible indication of rectifier quality, it is strongly recommended that tests be made under these conditions.

The simple half-wave circuit is shown in Figure 1. The capacitor is made large enough so that the ripple voltage across it is small compared with the applied alternating voltage. The voltage across the rectifier and series resistance is the

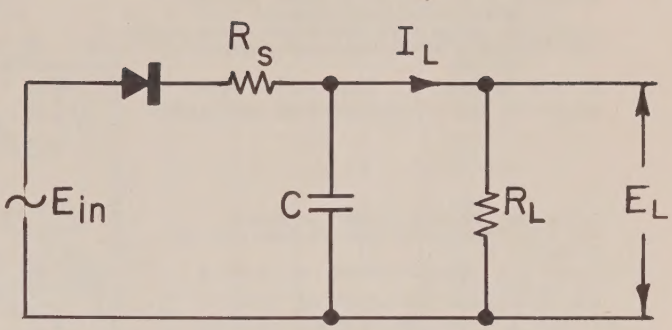


Figure 1. Basic Half-Wave Capacitor-Input Rectifier Circuit.

difference between the input voltage and the nearly constant capacitor voltage, and current flows only when the applied voltage exceeds the capacitor voltage, as shown by the shaded area of Figure 2. During this part of the cycle the current is limited only by the rectifier resistance and the added series resistance R_S.

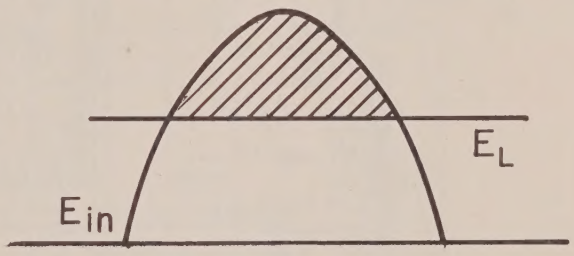


Figure 2. Conducting Part of Cycle when Large Load Capacitor is Used.

In establishing the load conditions the minimum required capacitance must first be determined. Any value of capacitance greater than this can be used without appreciable effect on the operating conditions, except for transient effects when voltage is first applied. The rule is that

$$R_L C\omega > 20$$

where the resistance is in ohms and the capacitance is in farads. Note that

$$R_L = \frac{E_L}{I_L} .$$

For a frequency of 60 cps and for capacitance expressed in microfarads, the required capacitance is,

$$C_{\mu f} > \frac{53{,}000}{R_L}$$

Let us take as standard load conditions a capacitance substantially larger than the above limiting value and a series resistance to make the rms to dc current ratio exactly 2.5. Calculations show that this requires a series resistance

$$R_S = 0.028\ R_L$$

NOTE:
RESISTORS 1/2 WATT UNLESS OTHERWISE SPECIFIED.
RESISTANCE IN OHMS UNLESS OTHERWISE SPECIFIED.
K = 1000 OHMS M = 1 MEGOHM
CAPACITANCE VALUES ONE & OVER IN MICRO MICRO-FARADS, LESS THAN ONE IN MICROFARADS, UNLESS OTHERWISE SPECIFIED.

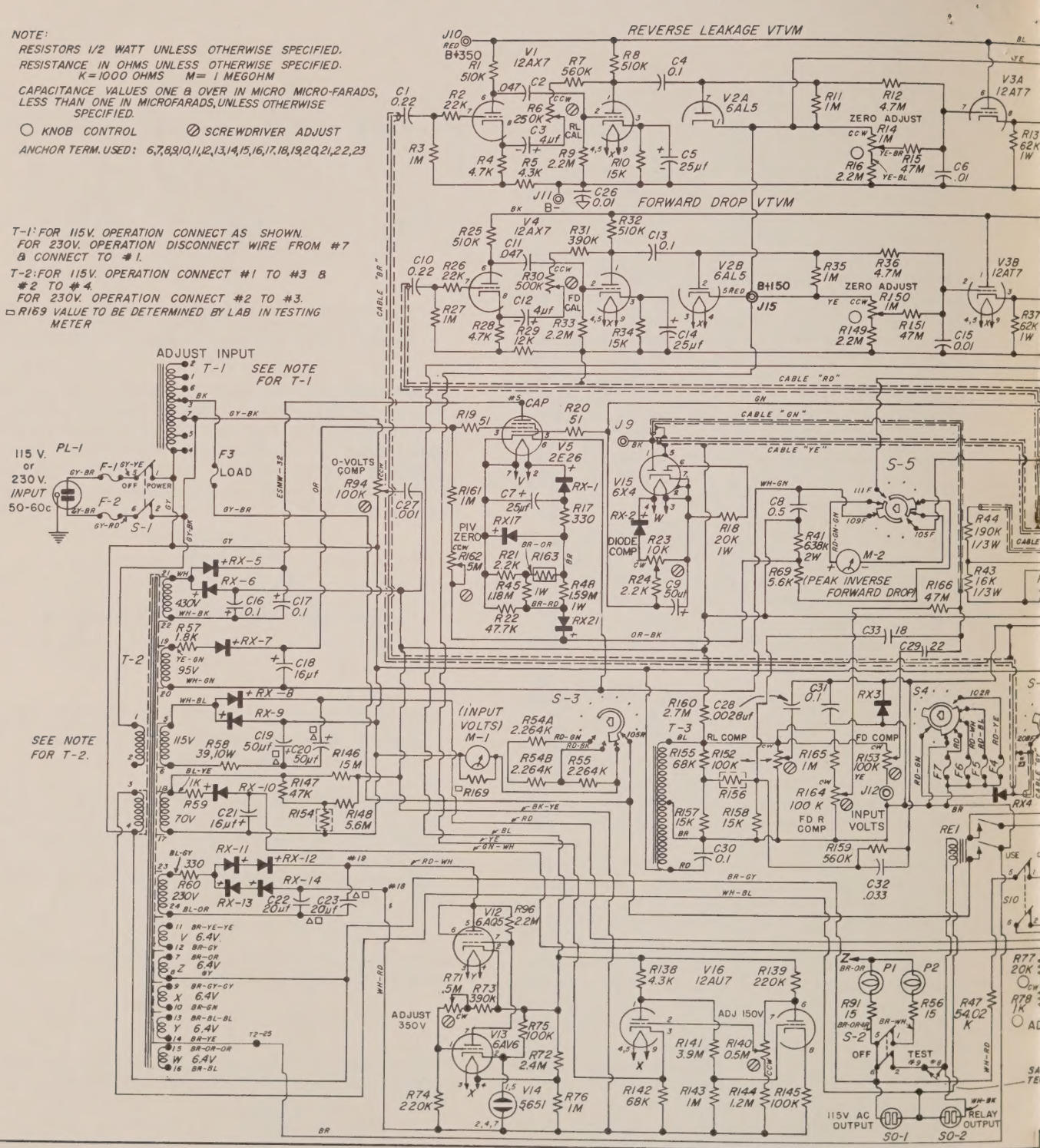
○ KNOB CONTROL ⊘ SCREWDRIVER ADJUST

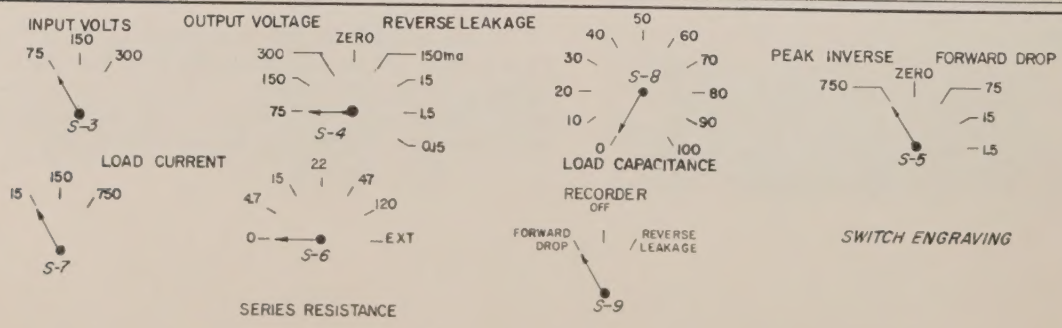
ANCHOR TERM. USED: 6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23

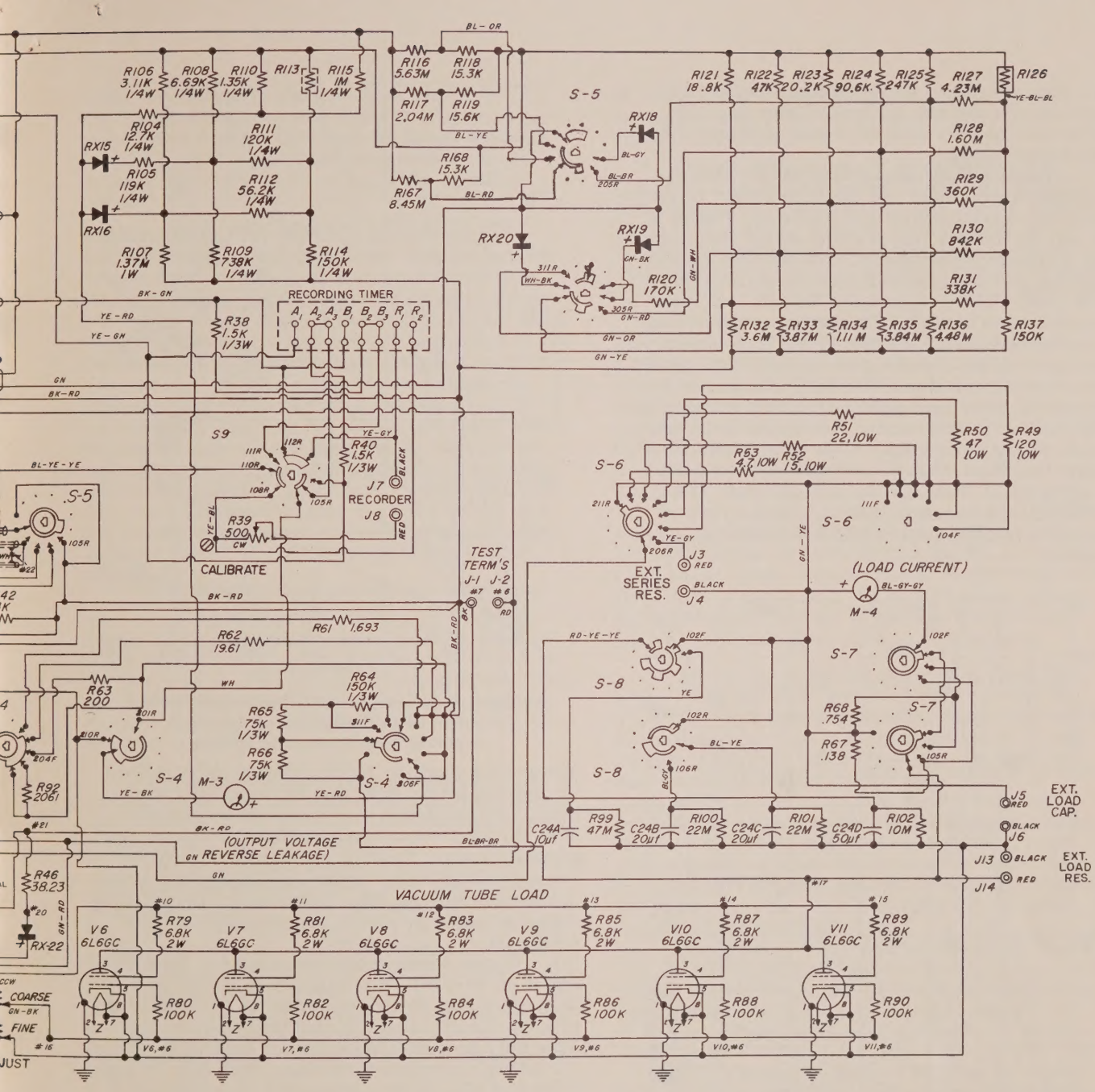
T-1: FOR 115V. OPERATION CONNECT AS SHOWN.
FOR 230V. OPERATION DISCONNECT WIRE FROM #7 & CONNECT TO #1.

T-2: FOR 115V. OPERATION CONNECT #1 TO #3 & #2 TO #4.
FOR 230V. OPERATION CONNECT #2 TO #3.

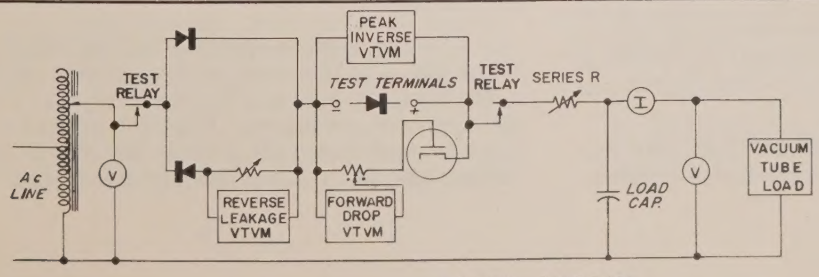
□ R169 VALUE TO BE DETERMINED BY LAB IN TESTING METER







SCHEMATIC DIAGRAM
FOR
1280-A RECTIFIER TEST SET



BLOCK DIAGRAM

The peak current under these conditions is 7.83 times the dc current; the load voltage is 1.163 times and the peak inverse voltage 2.58 times the rms input voltage.

These ratios make it easy to calculate the minimum capacitance and required series resistance for various operating conditions. Figure 3 shows, for various values of the series resistance, the combinations of input voltage and load current that will give the standard peak-to-average current ratio. The straight lines indicate that for a constant value of series resistance the input voltage must be varied in proportion to the load current to maintain the same current waveform. The hyperbolas are curves of constant watts dissipation in the series resistance under the standard conditions. The series resistors in the instrument have a maximum rating of 10 watts. When test conditions require a higher rating, an external series resistor must be used. This is done by turning the SERIES RESISTANCE switch to EXT and connecting the required resistance at the EXT SERIES RES terminals.

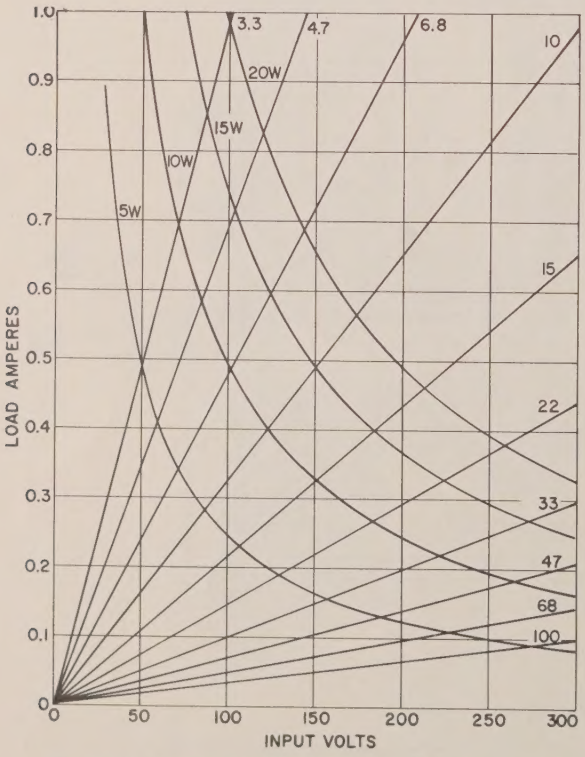


Figure 3. Required Values of Series Resistor (Straight Lines) for Standard Capacititive Load Conditions. Also (Hyperbolas) Required Dissipation in Series Resistor.

Figure 4 shows the minimum required capacitance for various conditions of input voltage

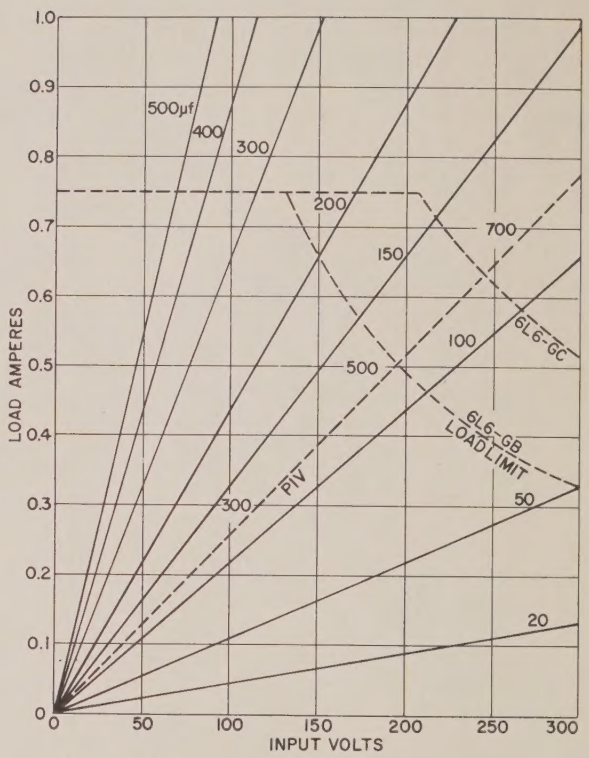


Figure 4. Minimum Required Capacitor for Standard Conditions. Also (Dashed Lines) Load Limit and Approximate Peak Inverse Voltage.

and dc load current. Here again the straight lines through the origin show that the required capacitance, like the series resistance, is unchanged when the input voltage and load current are varied proportionally. The diagonal dashed line shows the approximate peak inverse voltage as a function of the input voltage, the ratio between the two being 2.58, as mentioned above, for the standard load conditons.

Figure 4 also shows the maximum load rating of the test set. The basic limit of 750 ma must be reduced at the higher voltages because of the plate dissipation limit of the vacuum-tube load. This limit is indicated by the two dashed parabolas for the two alternative load tubes, Type 6L6-GB and Type 6L6-GC. Load current up to the 750 ma maximum can be drawn even at high voltage by connecting an auxiliary load resistor to the EXT LOAD RES terminals to handle the difference between the required load and that which can be handled by the vacuum-tubes.

Let us suppose, that we want to test a rectifier with a peak inverse voltage rating of 400 at a dc output current of 300 ma under standard capacitive load conditions. Figure 3 shows that with a series resistance of 15 ohms the required input voltage should be 138. The heat dissipation in the

series resistance is about 8 watts, within the 10-watt rating of the resistor in the instrument. Figure 4 shows that a capacitance of 100 μf is just sufficient, and that the peak inverse voltage will be about 355 volts, which is below the rectifier rating.

CALIBRATION AND SERVICE ADJUSTMENTS. The calibration of the instrument depends on proper setting of the internal power-supply voltages, on compensation of the contact potential of the diode rectifier used in the forward drop circuit and on setting the gain of the feedback amplifiers in the forward-drop and reverse-leakage circuits to give correct readings on the internal standards provided. In addition, there is an internal adjustment of the zero of the PIV meter, and there are two adjustments in both the forward drop and reverse leakage circuits for balancing inter-winding capacitance effects. These latter adjustments prevent any interaction between the input Variac setting and the meter zeros. Readjustment is seldom required unless tubes in these circuits are replaced.

To make these adjustments the instrument must be removed from the cabinet. The required screw-driver controls are then readily accessible on the upper side of a sub-chassis in the center of the instrument. This sub-chassis is insulated from the main chassis, and may be at a potential above ground. An insulated screwdriver should be used for adjustments 4,5 and 6 described below.

The balance adjustments should not be attempted unless the instrument is properly grounded and the polarity of the line cord checked as described in the operating section.

1. Adjusting Power-Supply Voltages. After the instrument has warmed up for a few minutes, connect a good voltmeter between the B- and B+ 350 pin jacks on the sub-chassis. Set the ADJUST 350V control as required. The TEST switch should be at OFF for this adjustment and the sub-chassis will then be at ground potential.

Next move the positive voltmeter lead to the B+ 150 pin jack and adjust the corresponding control as required. Note that B+ 350 must be adjusted first.

2. Adjustment of PIV Zero. Leave the TEST switch OFF and short the rectifier test terminals. Turn the meter control to PEAK INVERSE. Adjust the zero as required by means of the PIV ZERO control on the sub-chassis.

3. Diode Compensation. With the TEST switch OFF and the rectifier test terminals shorted as before, connect a sensitive dc vacuum-tube voltmeter between the B- pin jack and the jack marked J9. (The positive voltmeter terminal should be connected to the B-jack.) Adjust to 50 millivolts with the DIODE COMP control. Any meter with an input resistance of 10 megohms or higher may be used. The low impedance side of the meter should go to the B- point, if possible.

4. Balance Adjustments of Reverse-Leakage Circuit. The zero settings of the four RL ranges will coincide when the TEST switch is OFF and the Variac set at zero. When the TEST switch is on, current through the wiring capacitance can cause a zero shift on the most sensitive RL range, 0-150 μa. This can be neutralized by the following adjustments.

a. With the SERIES RESISTANCE at 4.7 ohms and the LOAD CAPACITANCE at 100 μf, connect a silicon rectifier such as a 1N-536 to the test terminals. Set the Variac® Autotransformer to zero and turn the TEST switch on. Set the RL zero carefully and then turn the range switch from ZERO to the 0.15 ma range and note if the zero shifts. If it does, correct it with the 0 VOLTS COMP control on the sub-chassis. Then turn the TEST switch off.

b. Remove the rectifier, turn up the ADJUST control for LOAD CURRENT about half way, turn the TEST switch on, and, leaving the RL meter on the 0.15 ma range, turn the Variac® Autotransformer from zero to maximum. If the zero shifts, adjust by the RL COMP control on the sub-chassis when the Variac® Autotransformer is at maximum.

5. Balance Adjustments of Forward-Drop Circuit. When the TEST switch is off, the zeros of all three FD ranges will coincide with or without a rectifier at the test terminals and at any Variac setting. With the TEST switch on, a rectifier at the test terminals and the FD range switch at 1.5 volts, there should be no reading at no load and zero Variac setting, but a slight reading of about 0.01 volt should be observed when voltage is applied because of slight circuit losses. As the Variac is turned up there will also be a momentary reading of the FD meter resulting from the charging current of the load capacitor.

In addition to these normal effects there can also be a zero shift unless inter-wiring capacitance effects are balanced out. This is accomplished by two adjustments on the sub-chassis labeled FD COMP and FD R COMP. The procedure is as follows:

With a series resistance of 4.7 ohms, a load capacitance of 100 μf and a silicon rectifier at the test terminals, turn the TEST switch on. Turn the Variac up to a voltage safely below the breakdown point of the rectifier. A slight FD reading will be observed as noted above. Adjust the FD COMP and FD R COMP controls on the sub-chassis until this is a minimum, usually 0.03 volt or less. This residual from stray current flow has negligible effect on readings when normal load current is taken.

6. Calibration Adjustments. The gain of the feedback amplifiers in the forward-drop and reverse-leakage voltmeter circuits can be set at the correct

values by the use of internal standards simulating the rectifier under test. The RL circuit is calibrated in terms of the current produced by a measured ac voltage applied to a standard resistance. The FD circuit is calibrated in terms of a current having a known waveform and known dc component flowing through a standard resistance and a calibrated rectifier. The rectifier drop is only a few percent of the total, so that an accurate calibration is obtained.

These adjustments must be made with no rectifier at the test terminals and with the SERIES RESISTANCE set to zero. The load capacitance should be 100 μf. Turn the toggle switch on the sub-chassis from USE to CAL. Carefully set the RL and FD zeros and switch the RL circuit to the 1.5 ma range and the FD circuit to the 15 volt range. Turn the TEST switch on. Set the input at 120 volts and the load current at 100 ma. The RL meter should read 1.0 ma and the FD meter 10.0 volts. Any required correction can be made at the RL CAL and FD CAL controls on the sub-chassis. After adjustment, turn off the TEST switch, and return the toggle switch on the sub-chassis from the CAL to the USE position.

CONDENSED PARTS LIST

(For values of other Components, refer to Schematic Diagram)

RESISTORS

R92	2061Ω ±1/4%	1280-201-4
R113	(THERMISTOR R174)	1280-44
R126	(THERMISTOR R174)	1280-44
R154	(THERMISTOR R171)	1280-45
R156	(THERMISTOR R171)	1280-45
R163	(THERMISTOR R174)	1280-44

RECTIFIERS

RX1	1N1692	RX12	2RE-29
RX2	1N1692	RX13	2RE-29
RX3	2RE-41	RX14	2RE-29
RX4	IN536	RX15	IN536
RX5	2RE-27	RX16	IN536
RX6	2RE-27	RX17	1N751A
RX7	2RE-28	RX18	IN536
RX8	2RE-7	RX19	IN536
RX9	2RE-7	RX20	IN536
RX10	2RE-28	RX21	IN536
RX11	2RE-29	RX22	IN538
	RX23	IN536	

FUSES

	For 115 V:			
F1	3.0 Amps	3AG	Slo-Blo	FUF-1
F2	3.0 Amps	3AG	Slo-Blo	FUF-1
	For 220 V:			
F1	1.5 Amps	3AG	Slo-Blo	FUF-1
F2	1.5 Amps	3AG	Slo-Blo	FUF-1
F3	3.0 Amps	AGC	Fast Acting	FUF-2
F4	1 Amp	AGC	Fast Acting	FUF-2
F5	0.5 Amp	AGC	Fast Acting	FUF-2
F6	0.1 Amp	AGC	Fast Acting	FUF-2
F7	1/32 Amp	AGC	Fast Acting	FUF-2

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS

PHILADELPHIA: 1150 York Road
Abington, Pennsylvania
WASHINGTON: 8055 13th Street
Silver Spring, Maryland

NEW YORK: Broad Avenue at Linden
Ridgefield, New Jersey
CHICAGO: 6605 West North Avenue
Oak Park, Illinois
CANADA: 99 Floral Parkway
Toronto 15, Ontario

LOS ANGELES: 1000 North Seward Street
Los Angeles 38, California
SAN FRANCISCO: 1186 Los Altos Avenue
Los Altos, California

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An Accurate And Versatile Test Instrument For Semiconductor Rectifiers

W. N. Tuttle

A long-standing and difficult problem has been that of testing silicon, germanium, and selenium rectifiers of the types now generally used in power supplies for electronic equipment. Power supply failures are responsible for much service difficulty, and it is important to be able to buy rectifiers that will meet specifications based on reproducible tests. In addition, a flood of new rectifiers is reaching the market, and many new manufacturers are entering the field. It is of great value to be able to analyze in detail the performance of new rectifiers to discover characteristics that might lead to service failure. The Type 1280-A Rectifier Test Set is now offered as a solution to both these problems and provides accurate quantitative measurements on which specifications can be based as well as detailed qualitative data on performance under actual operating conditions.

An ideal rectifier would have zero voltage drop in the forward direction and zero leakage in the reverse direction. Measures of forward drop and reverse leakage, which are the deviations from the ideal, are the basic rectifier parameters. The forward drop determines the maximum current which can be carried without excess heating and so determines the current rating. The reverse leakage characteristic, in a similar fashion, determines the peak-inverse-voltage rating.

In the development of the test instrument, circuits were sought which could be calibrated in absolute terms. Also, if actual operating conditions of the rectifier were to be reproduced, it was necessary that the rectifiers be tested with the high peak-to-average current ratios that prevail in the usual capacitor-input power-supply circuit. Even when a rectifier is intended for use with a resistive or inductive load, tests at high peak current are desirable, because they explore a larger portion of the characteristic curve and provide a more sensitive indication of rectifier quality. Finally, it was felt to be essential to make the forward-drop and reverse-leakage tests simultaneously because of the effects of forward current on reverse leakage, and of reverse voltage or current on the forward drop.

The most obvious interaction between the forward and reverse characteristics is through the temperature rise, and it is clearly important for tests to be made at the equilibrium temperature corresponding to the maximum ratings. But there are other kinds of interaction. After a rectifier conducts a heavy pulse of forward current, a finite time is required for carrier dissipation and the recovery of high reverse resistance. This shows up as an increase in reverse leakage when the forward current is increased. Another effect is that forward current may markedly alter the reverse leakage of rectifiers suffering from surface contamination. Finally, in selenium rectifiers, which are usually not so stable as silicon or germanium rectifiers, it is sometimes found that reverse voltage affects the forward drop through its reforming effect on the rectifying junction.

The circuits finally adopted for the Type 1280-A Rectifier Test Set have the desirable characteristics above outlined. Forward drop and reverse leakage are measured simultaneously, the measurements are made under high-peak-current conditions, and the circuits are stable and can be accurately calibrated. In addition to these basic characteristics there are other important features of the instrument that contribute greatly to its versatility and convenience of operation.

The first of these plus values is a direct-reading meter for indicating the actual operating peak inverse voltage. This quantity is basic in rectifier ratings, but is hard to estimate from the applied ac voltage and the circuit constants. Readings of reverse leakage are meaningless unless correlated with accurate determinations of peak inverse voltage. In addition to providing a basis for leakage specifications below the breakdown point, the PIV meter makes possible the convenient and direct determination of the Zener voltage of power rectifiers, although it is not intended for testing Zener regulators in the 4-20 volt range.

Adjustment of the load current has been a bugaboo in rectifier testing, particularly when a wide range of load currents must be covered. This problem has been solved in the Type 1280-A Rectifier Test Set by

providing a bank of power tubes, in place of an aggregation of adjustable resistors, to carry the load current. The load control is a small potentiometer determining the grid bias of the power tubes, and it permits the setting of load currents from less than a milliampere to 750 ma with equal convenience and accuracy.

A third feature of the instrument is that linearizing circuits are employed in the three vacuum-tube voltmeters reading forward drop, reverse leakage and peak inverse voltage, so that these quantities can be measured on large, linear, open-scale multipurpose instruments. Three ranges of forward drop and four ranges of reverse leakage can be accurately measured on their respective instruments using only a single linear scale for each.

The circuit for measuring forward drop and reverse leakage are arranged so that a recorder can be connected externally to show the variation of these quantities with time or during the warm-up cycle. Use of the panel meters is not interrupted when the recorder is switched in. An additional advantage of the linearizing circuits is that forward drop and reverse leakage can be read directly on linear recording paper. A panel switch permits the recorder to be connected into either the forward-drop or reverse-leakage circuit.

THE CIRCUIT

The basic circuit of the instrument is the simple half-wave, capacitor-input rectifier circuit in which the input ac voltage, the series resistance, the load capacitance and the load resistance are separately adjustable. To this circuit have been added a pair of rectifiers to separate the forward and reverse currents, and three vacuum-tube voltmeters for reading forward drop, reverse leakage and peak inverse voltage. Also, a bank of vacuum tubes is substituted for the adjustable resistor, giving the final arrangement of Figure 1.

This method of testing is not new, and circuits of this kind have been used in the production testing of selenium rectifiers for many years. However, as used in the past they have not been sufficiently stable, nor have they been capable of direct calibration so that specifications could be based on their readings. These difficulties were greatly aggravated when it was attempted to measure forward drop of a few tenths of a volt and reverse leakage of a microampere or less, as required in the testing of silicon and germanium rectifiers.

Overcoming these difficulties has required several years of effort. Without going into the details, the following improvements have changed this circuit from one capable of rough checks only to one of stability, precision and versatility.

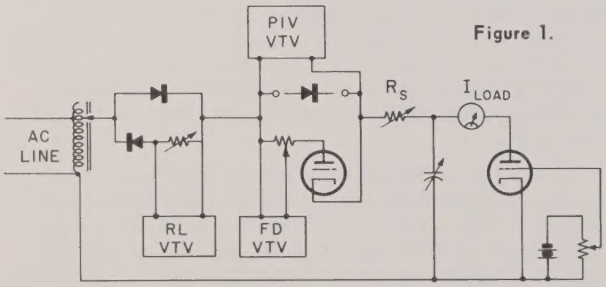

Figure 1.

(a) The use of silicon rectifiers greatly improves the separation of the forward and reverse components of the current. Reverse leakage of a fraction of a microampere can be indicated in the presence of a peak forward current of 3 or 4 amperes, a separation ratio of several million to one.

(b) The use of vacuum-tube voltmeters of the amplifying type for the measurement of forward drop and reverse leakage greatly increases sensitivity. In the case of the forward-drop circuit it also enables the vacuum-tube diode in the measuring loop to operate on the reproducible exponential-cutoff part of the plate-current curve, making the calibration independent of the tube. Compensation is made for contact-potential variations. Overloads or short circuits can not damage the meters.

(c) Balancing the circulating currents flowing through the stray capacitances eliminates reverse-leakage errors from this source. This balance adjustment is fixed, and independent of applied voltage and temperature.

(d) Absolute methods of calibration have been developed for both the forward-drop and reverse-leakage circuits. The forward-drop calibration is in terms of a direct current and a standard resistance. The reverse leakage calibration is in terms of an ac voltage and a standard resistance. Standards are built into the instrument and permit periodic checking of the calibration.

PANEL ARRANGEMENT AND OPERATION

The panel arrangement is shown in the photograph, Figure 2, and approximates the circuit diagram of Figure 1. The meter and control for the applied ac voltage are at the left. The load current meter and control are at the top center. The meter at top right reads either output dc voltage or reverse leakage. The meter at the lower right reads either peak inverse voltage or forward drop. Left of center is a control for setting the series resistance to one of several standard values or to a special value connected externally. The load capacitance switch to right of center gives decade values from 10 to 100 μf,

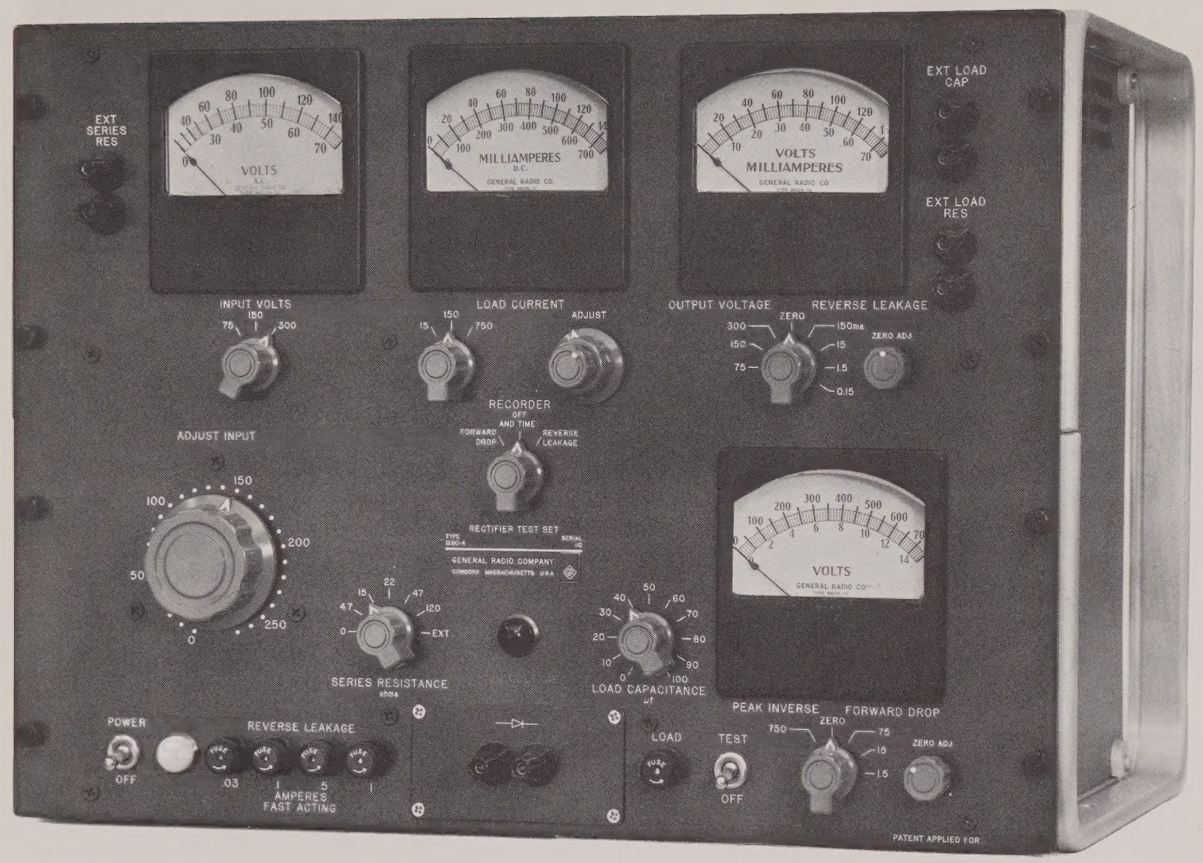

Figure 2.

and additional capacitance can be connected externally. Test terminals are at the bottom center. Both terminals are disconnected from the power source until the test switch is thrown, operating a relay to connect the rectifier in circuit. The relay also operates a red light warning that voltage is across the rectifier terminals.

With this layout the operation is simple both in concept and in practice. It is evident to the user that he is connecting the rectifier into the type of circuit in which it will generally be used, and that he then adjusts the circuit constants, the applied voltage and the load current to standard values corresponding to the ratings of the rectifier. He can then measure the rectifier parameters directly on the panel meters without disturbing the operation of the basic circuit.

EXAMPLES OF RESULTS

Use of the instrument quickly brings to light many characteristics of rectifiers and their circuits that are not generally appreciated. The voltage across a silicon or germanium rectifier is approximately a logarithmic function of the current through it, as shown in the curve of Figure 3. When a sharply peaked current waveform is applied, the average voltage across the rectifier, for a given average or dc current, is much less than when the current is a half sine wave. This is because the instantaneous voltage drop increases much less than in proportion to the current. Figure 4 gives the full-cycle average forward drop for a Type IN-536 silicon rectifier as a

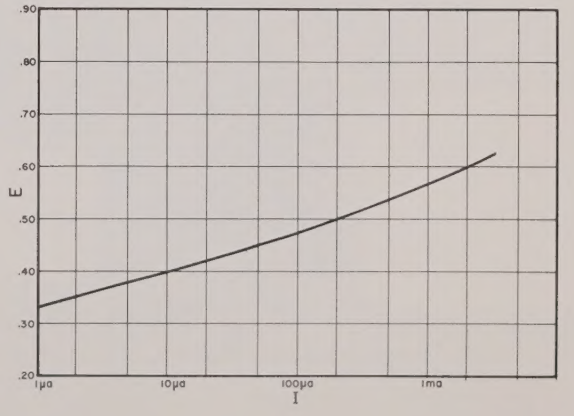

Figure 3.

function of the rms-to-average ratio of the rectifier current. The average or dc value of the current is held constant at 100 ma. For a resistive load, corresponding to an rms-to-average current ratio of 1.57 and a peak-to-average current ratio of 3.14, the average drop is 0.408 volt. For a very peaked waveform, for which the corresponding ratios are 3.2 and 12.8, the average drop is only 0.121 volt, a reduction of more than three to one. The extreme peaking of the second example is not usually good engineering practice. An rms-to-average current ratio of 2.5 is a better practical choice. With a sufficiently large capacitor the sharpness of the peak is determined by the ratio of the series resistance to the load resistance, a desirable value being two or three per cent.

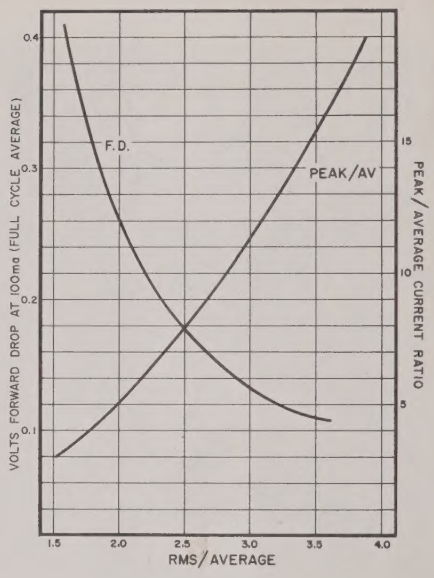

Figure 4.

SPECIFICATIONS

Input Voltage:	Adjustable from 0-300 v rms, at 50/60 cycles in 3 meter ranges (0-75 v, 0-150 v, 0-300 v).
Load Current:	Adjustable from 0-750 ma, dc, in 3 meter ranges (0-15 ma, 0-150 ma, 0-750 ma).
Load Voltage:	0-300 v, dc, in 3 meter ranges (0-75 v, 0-150 v, 0-300 v). Allowable load current is 0-750 ma for output voltages up to 240 volts, decreases proportionally at higher voltages to 600 ma at 300 v.
Reverse Leakage Current:	0-150 ma, dc, (reads time average of waveform) in 4 ranges (0-150 μa, 0-1.5 ma, 0-15 ma, 0-150 ma).
Peak Inverse Voltage:	0-750 v peak.
Forward Drop:	0-75 v, dc, (reads time average of waveform) in 3 ranges (0-1.5 v, 0-15 v, 0-75 v).
Load Capacitance:	Adjustable from 0-100 μf in 11 decade steps. Oil-filled paper capacitors are used to give negligible leakage current even with very light loads. Additional load capacitance may be added by utilizing EXT LOAD CAP binding posts.
Series Resistance:	Internal values 4, 7, 15, 22, 47 and 120 ohms. Other values can be connected at EXT SERIES RES terminals.
Accuracy:	±2% of full scale (better at low end).
Dimensions:	19" wide x 14" high x 13" deep (suitable for relay rack mounting). (485 x 360 x 335 mm.)
Weight:	Approximately 50 lbs (23 kg).
Power:	100 watts (standby) up to 300 watts when supplying load current.
Accessories Supplied:	Power cable, 7 fuses.

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